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Results of Employing a Modified Reticle Designed To Assist the Gunner in Compensating for Trunnion Cant in Tanks (U)

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Results of Employing a Modified Reticle Designed To Assist the Gunner in Compensating for Trunnion Cant in Tanks (U)

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FOREWORD

The effects of trunnion cant are significant when firing ammunition with muzzle velocities of 2500 fps or lower.

This paper presents the conduct and analysis of data resulting from an experiment (conducted at Ft Stewart, Ga., during the period 23 June–4 July 1963) designed to evaluate the effectiveness of a modified reticle and to assist the gunner in compensating for the effects of trunnion cant.

The use of ballistics computers that automatically correct for the effects of trunnion cant is the most satisfactory solution. The data presented here show that cant is an important source of gunnery error and that the employment of a modified reticle as an interim measure to assist the gunner in compensating for cant results in increased accuracy of fire.

R. E. Tiller
Chief, Field Experiments
Division

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Mr. Harry Charnock, Mr. Walter Hollis, and their coworkers at the Frankford Arsenal are cited for their excellent work in engraving the modified reticles used in the experiment.

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SUMMARY

Problem

To assess the performance of tank gunners employing a modified reticle to assist in compensating for the influence of trunnion cant in the M60 tank main gun.

Facts

Trunnion cant decreases hit probability of the 105-mm high-explosive plastic (HEP) round at normally expected combat ranges (500 to 1500 m). An earlier RAC publication[1] considered cant as a fixed bias and proposed an interim measure as compensation. Ballistics computers that will automatically correct for trunnion cant and other major sources of tank-gunnery errors, such as parallax, drift, jump, and crosswind, will ultimately provide the most satisfactory solution. This memorandum describes an experiment using a modified reticle to compensate for cant when firing high-explosive plastic tracer (HEP-T) and high-explosive antitank tracer (HEAT-T).

Discussion

During the period 23 June–4 July 1963 an experiment was conducted at Ft Stewart, Ga., to compare the hit probabilities resulting from firings by experienced gunners using the M60 tank standard reticle with those resulting from firings by a different group of experienced gunners using a reticle modified with engraved aim-offs to correct for the effects of trunnion cant. A total of 379 (including zeroing and warm-up rounds) 105-mm rounds of ammunition was fired during the experiment under controlled conditions.

The factors of degree of trunnion cant, direction of trunnion cant, and target range were investigated to determine their effects on hit probability when using both the standard and a modified reticle.

Miss distances from the center of the target were the experimental data collected. An analysis of miss distances was performed to assess the increased accuracy resulting from the use of a modified reticle.

The effects of trunnion cant are significant when firing ammunitions with muzzle velocities of approximately 2500 fps or lower, but they are relatively minor for high-velocity ammunitions (3000 fps or higher) at normally expected

SUMMARY

combat ranges. Although these results may be pertinent only to the M60 tank firing HEP without the aid of an automatic ballistics computer, they will be of importance in the development of future weapons systems possessing capabilities of firing either guided missiles or low-velocity ballistic projectiles. It is necessary that the design of these new weapons incorporate a system that will compensate for trunnion cant and other sources of tank-gunnery errors.

Conclusion

The employment of a modified reticle will compensate for the effects of trunnion cant by significantly increasing hit probability of the standard non-ballistic reticle. In addition to increasing first-round hit probability the employment of the modified reticle will significantly increase the overall first- or second-round hit probability by a factor of 1.5 to 2 over canted firings utilizing the standard reticle.

Results of Employing a Modified Reticle Designed To Assist the Gunner in Compensating for Trunnion Cant in Tanks

ABBREVIATIONS

APDS-T	armor-piercing discarding-sabot tracer (ammunition)
BC	battery commander
CDC	Combat Developments Command
HEAT-T	high-explosive antitank tracer (ammunition)
HEP	high-explosive plastic (ammunition)
HEP-T	high-explosive plastic tracer (ammunition)
MTB	medium tank battalion
SFC	sergeant first class
TP-T	training practice tracer (ammunition)

INTRODUCTION

This study had its origins in the work of a RAC field team that conducted experiments in Germany during March–April 1962, with the 1st MTB, 32d Armor, 3d Armd Div. Gun cameras were used on M60 tanks in the experiments, and during the film analysis it was observed that a "majority of the fire pictures indicated that the firing tank had a noticeable amount of trunnion cant—one time as high as 20 deg."[1] Calculation of the change in impact point due to firing from a canted position predicted[1] a considerable degradation in first-round hit probability, particularly for HEP ammunition. This prediction was realized in some preliminary firings done from canted positions during field experiments in Germany in July–August 1962.

The demonstration of the cant-produced degradation in hit probability evoked proposals for compensating devices, the most readily applicable being a reticle with additional aiming crosses engraved on it.[1] The position of each cross was to be calculated to produce a first-round hit at a given range with a particular degree of cant. Such a modified reticle was used in a cant experiment[2] with the M60 tank 105-mm main gun at Ft Knox, Ky. during April 1963. Firings from tanks with standard, unmodified reticles under similar conditions were conducted for comparison; the results with the modified reticle were substantially better.

The purpose of the present study, like that of the Ft Knox experiment, is to assess the performance of a modified reticle relative to the standard non-ballistic reticle for the M60 tank 105-mm main gun firing from canted positions. At Ft Knox each shot was recorded only as a target hit or a miss; in this study the coordinates of the impact point are measured (with the center of the target cross as origin) for each shot. This determination of the distribution of impact points affords a better estimate of hit probability than does the fraction of shots hitting the target.

CONDUCT OF EXPERIMENT

Modified Reticle

The standard M60 reticle was modified by engraving auxiliary aim-off crosses on it as illustrated in Fig. 1. The positions of the crosses were calculated[1,3] to produce first-round hits at 1200 m with HEP-T ammunition for guns, zeroed with armor-piercing discarding-sabot tracer (APDS-T) ammunition at 1200 m. The angular coordinates of the engraved crosses for the 6 deg of cant considered are given in Table 1.

In the primary phase of the experiment training practice, tracer (TP-T) ammunition was used to simulate the ballistic characteristics of HEP-T while

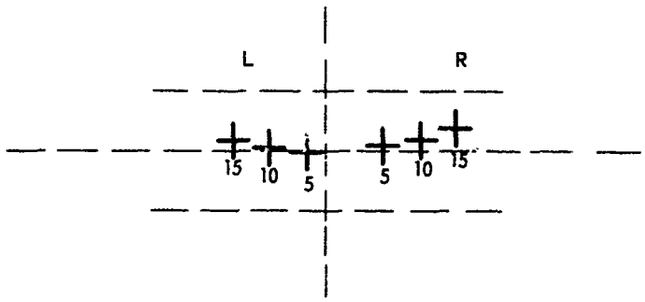

Fig. 1—Modified Reticle with Auxiliary Aim-off Crosses for 5, 10, and 15 Deg of Cant

TABLE 1

Coordinates of Aim-off Points Engraved on Modified Reticle

Cant magnitude,[a] deg	Aim-off coordinates, mils	
	Horizontal	Vertical
15 L	−3.24	0.31
10 L	−1.97	0.09
5 L	−0.66	−0.01
5 R	1.94	0.12
10 R	3.22	0.35
15 R	4.47	0.70

[a]L, left; R, right.

avoiding its destructive capability. In the secondary phase a limited number of HEAT-T rounds were fired to assess the importance of trunnion cant on ammunition with a considerably higher muzzle velocity (3800 fps as compared with 2400 fps for HEP-T[4]).

Range Layout

Figure 2 shows the layout of the firing range used for the experiment. The targets were positioned from left to right, as one looks downrange, at distances of 800, 1200, 1500, and 2000 m. TP-T ammunition was fired on the targets at 800, 1200, and 1500 m, and HEAT-T at 2000 m.

Each target consisted of a 6- by 8-ft canvas panel mounted on wooden frames and centered on a 35-ft-square wire screen supported by wooden poles. The wire screen allowed measurement of the impact point coordinates of those

rounds that missed the canvas panel. A 2- by 2-ft cross was laced in the center of each panel to provide the gunners with a well-defined aiming point.

The cant ramp was constructed of earth graded into a mound. The slope on either side of the ramp allowed positioning a tank at the appropriate degree

Fig. 2—Experimental Layout of St Lo Range at Ft Stewart, Ga.

of hull tilt—5, 10, or 15 deg—so that the desired degree of trunnion cant could be introduced simply by rotating the turret 90 deg. These movements are illustrated in Figs. 3 and 4.

Procedure

Two different sets of four M60-qualified gunners were used in the firing tests. Firings with the standard reticle were conducted first in order to prevent the gunners from learning about the aim-offs on the modified reticle. The gunners using the standard reticle were considered to be above average, however, since three of them had fired from canted positions (but without a modified reticle) in a previous experiment in Germany. A description of the step-by-step experimental procedure is outlined in App A.

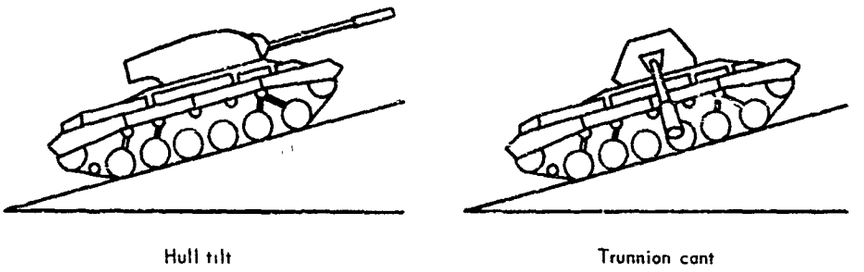

Fig. 3—Trunnion Cant from Hull Tilt

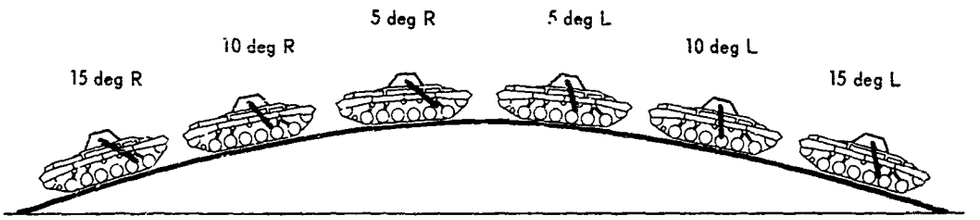

Fig. 4—The Six Firing Positions on the Cant Ramp

Each round fired was sensed by a spotter using a battery commander (BC) scope positioned at the firing line. This sensing information was given to the gunner to use in relaying the gun before firing the second round. Existence of this information also allowed two gunners to complete their firings from one position on the ramp before the field team went downrange to examine and repair the target panel and wire screen. Miss distances (i.e., impact-point coordinates), measured horizontally and vertically from the center of the canvas panel, were estimated to the nearest $\frac{1}{4}$ ft for shots striking the panel and to the nearest $\frac{1}{2}$ ft for shots striking the screen.

RESULTS

Hit Probabilities

Two hit probabilities were calculated directly from the miss distances, i.e., impact-point coordinates, measured during the experiment: the probability P_1 of scoring a first-round hit and the probability P_{2M} of scoring a second-round hit given a first-round miss. The standard procedure[5] for determining these probabilities involves calculation of the mean horizontal and vertical miss distances and the corresponding standard deviations, and the assumption that horizontal and vertical miss distances are normally and

independently distributed. These two probabilities can be used to calculate the probability $P_{1,2}$ of obtaining either a first-round or a second-round hit: (a) probability of first-round hit P_1; (b) probability of first-round miss, $1 - P_1$; (c) probability of first-round miss followed by second-round hit, $P_{2M}\ (1 - P_1)$; (d) therefore, $P_{1,2} = P_{2M}\ (1 - P_1) + P_1$.

The actual computation of these various probabilities was complicated by two problems in the experimental procedure: (a) sometimes a second round was fired after a first-round hit, contrary to the experimental design, either because the first round was sensed off the target or not sensed at all, or because the first round struck very close to an edge of the canvas panel, thus making impossible a decision from the firing line; and (b) for some rounds no impact points could be found on either the canvas panel or the wire screen.

In the analysis, second rounds following first-round hits were counted if the hits were at a target edge but omitted otherwise. Only two rounds were omitted for this reason: one HEP and one HEAT, both with the modified reticle.

Lost rounds, i.e., those for which no impact points were found on the screen or the panel, were treated in both of two ways: (a) observer-sensing estimates of miss distances were used, and (b) the rounds were not included in the analysis. The results from treatments a and b are tabulated separately. In treatment a, miss distances have been assigned as follows to rounds sensed off the screen; for rounds sensed wide to the left, assign – 20 ft for horizontal miss distance and do not include a vertical miss distance; wide right, 20 ft horizontal and ignore vertical; over screen, 20 ft vertical and ignore horizontal; under screen, – 20 ft vertical and ignore horizontal. This procedure is completely arbitrary, to be sure; it is simply one plausible way of including lost rounds in the calculation of hit probabilities. In the study, 11 rounds were lost, all with TP-T ammunition; 8 with the standard reticle, including 1 sensed in the screen; and 3 with the modified reticle, including 2 sensed in the screen.

In the experimental design three factors have been varied identically for both reticles: cant angle, cant direction, and target range. For TP-T firings three levels of cant angle, two of cant direction, and three of range were used; the same was true for HEAT-T firings, except that only one level of range was used. The experimental hit probabilities are given in Tables 2 and 3. Ninety-five percent confidence intervals were computed for the mean horizontal and vertical miss distances; these were used to calculate 95 percent confidence intervals for the hit probabilities, which are shown in parentheses in Tables 2 and 3.

Overall, the firings employing the modified reticle resulted in significantly higher hit probabilities than were obtained from the standard reticle firings. Of primary importance is the increased hit probability of first- or second-round fire employing the modified reticle in comparison to the standard reticle by a factor of 1.5 to 2.

Comparison of Observer-Sensing Data with Actual Miss Distance

A secondary objective of this experiment was to compare the impact-point coordinates estimated by using a BC scope at the firing line with the miss distances measured on the target panel or wire screen. Thirty-five

TABLE 2

Hit Probabilities with TP-T Ammunition

Factors	Level	Round	Standard reticle, incl lost rounds	Modified reticle, incl lost rounds	Standard reticle, excl lost rounds	Modified reticle, excl lost rounds
All	—	1	0.18[a] (0.16–0.18)[b]	0.39 (0.33–0.42)	0.26 (0.24–0.26)	0.41 (0.35–0.45)
		2	0.18 (0.15–0.19)	0.36 (0.31–0.36)	0.23 (0.19–0.24)	0.49 (0.43–0.50)
		1 or 2	0.33 (0 29–0.34)	0.61 (0.54–0.63)	0.43 (0.39–0.44)	0.70 (0.63–0.73)
Direction	L	1	0.15 (0.11–0.17)	0.28 (0.18–0.36)	0.24 (0.17–0.27)	0.30 (0.19–0.40)
		2	0.14 (0.07–0.18)	0.27 (0.17–0.31)	0.19 (0.10–0 23)	0.42 (0.27–0.49)
		1 or 2	0.27 (0.17–0.32)	0.47 (0.32–0.56)	0.38 (0.26–0.44)	0.60 (0.41–0.69)
	R	1	0.21 (0.15–0 25)	0.53 (0.46–0.54)	0.27 (0.19–0.32)	0.53 (0.46–0.54)
		2	0.26 (0.18–0.28)	0.56 (0.45–0.57)	0.28 (0.20–0.30)	0.56 (0.45–0.57)
		1 or 2	0.42 (0.30–0.46)	0.80 (0.70–0.81)	0.48 (0.35–0.52)	0.80 (0.71–0.81)
Angle, deg	5	1	0.27 (0.18–0 31)	0.48 (0.35–0.53)	0.34 (0.24–0.38)	0.48 (0.34–0.54)
		2	0.65 (0.39–0.75)	0.73 (0.41–0.82)	0.65 (0.39–0.75)	0.73 (0.41–0.82)
		1 or 2	0.75 (0 50–0 83)	0.86 (0.62–0.92)	0.77 (0.54–0.85)	0.86 (0.61–0.92)
	10	1	0.16 (0.12–0.17)	0.32 (0.21–0.37)	0.22 (0.15–0 24)	0.37 (0.24–0.44)
		2	0.11 (0.05–0.12)	0.56 (0.33–0.64)	0.15 (0.08–0.16)	0.56 (0.33–0.64)
		1 or 2	0.26 (0.17–0.28)	0.70 (0.47–0.77)	0.34 (0.22–0.37)	0.72 (0.49–0.80)
	15	1	0.13 (0.11–0.13)	0.38 (0.28–0.40)	0.24 (0.18–0.24)	0.38 (0.28–0.40)
		2	0.18 (0.12–0.19)	0 22 (0.13–0.25)	0.19 (0.12–0.20)	0.36 (0.22–0.40)
		1 or 2	0.29 (0.21–0.30)	0.52 (0.37–0.55)	0 38 (0.28–0.39)	0.60 (0.44–0.64)
Range, m	800	1	0.40 (0.31–0.42)	0.77 (0.62–0.88)	0.40 (0.31–0.42)	0 77 (0 62–0.88)
		2	0.08 (0.01–0.13)	0.76 (0.47–0.93)	0.14 (0.01–0.21)	0.76 (0.47–0.93)
		1 or 2	0.45 (0.32–0.49)	0.95 (0.80–0 99)	0.49 (0.32–0 54)	0.95 (0.80–0.99)
	1200	1	0 16 (0.12–0.16)	0.39 (0.26–0.47)	0 26 (0 21–0.26)	0.49 (0.31–0.61)
		2	0.26 (0.17–0 27)	0.32 (0.23–0.32)	0.26 (0.17–0.27)	0.74 (0.53–0.80)
		1 or 2	0.38 (0.27–0.39)	0.59 (0.43–0.64)	0.45 (0.34–0.45)	0 87 (0.68–0.92)
	1500	1	0.12 (0.09–0.12)	0 25 (0.19–0.26)	0.20 (0.14–0.21)	0.25 (0.19–0.26)
		2	0.22 (0.14–0.25)	0.33 (0.26–0 33)	0.23 (0.15–0.25)	0.33 (0.26–0.33)
		1 or 2	0.31 (0.22–0.34)	0.49 (0.40–0.50)	0 38 (0.27–0.40)	0.49 (0.40–0.50)

[a]Experimental hit probabilities.

[b]Range of hit probabilities determined from 95 percent confidence intervals of mean impact-point coordinates.

TABLE 3

Hit Probabilities with HEAT-T Ammunition

(All factors)

Round	Standard reticle	Modified reticle
1	0.34 (0.23–0.34)	0.47 (0 23–0.61)
2	0.24 (0 10–0.26)	0.68 (0.32–0.80)
1 or 2	0.49 (0.30–0.51)	0 83 (0.48–0.92)

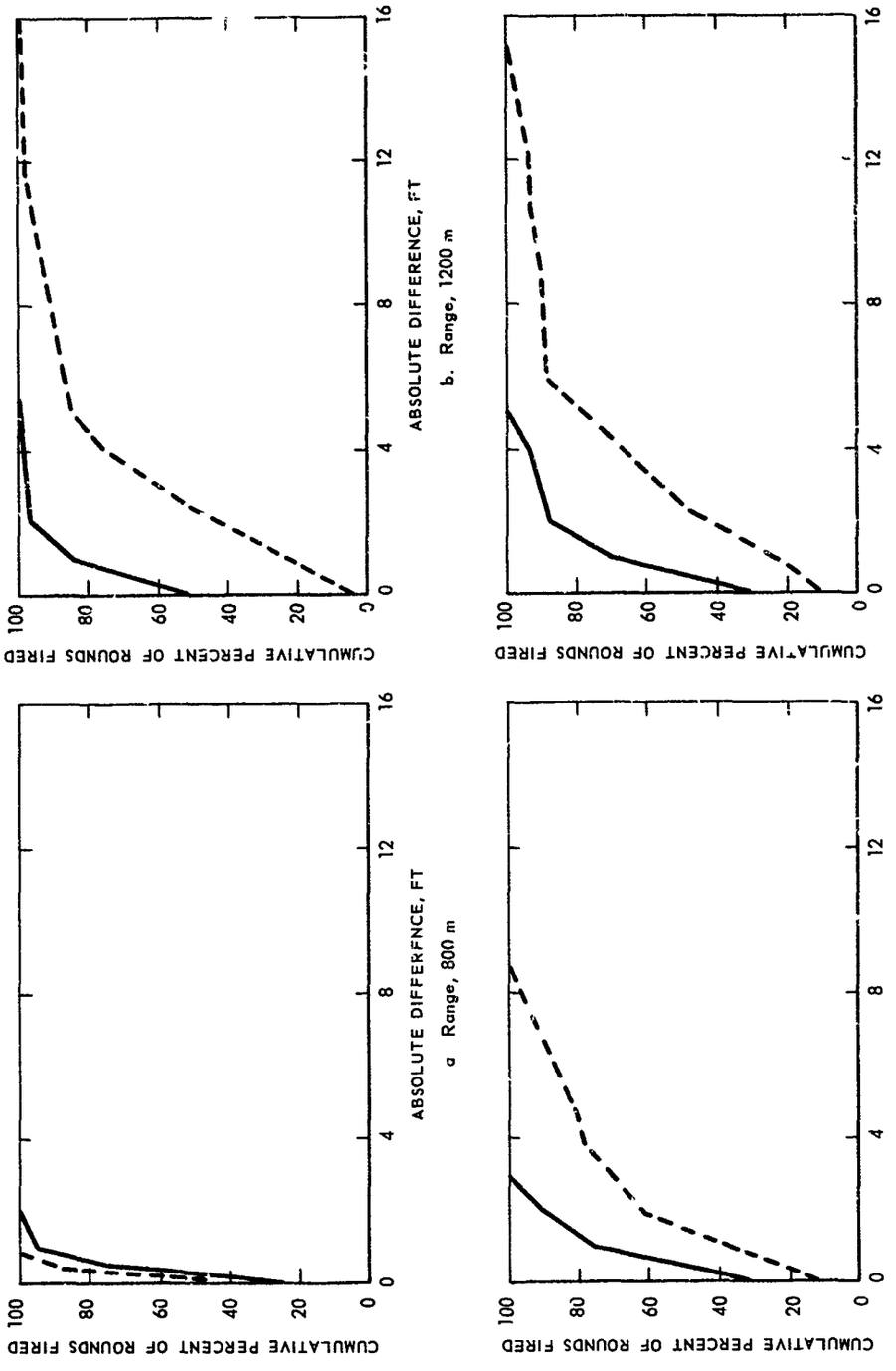

Fig. 5—Difference between Estimated Miss Distance Using the BC Scope and Actual Miss Distance at Different Target Ranges

percent of the rounds were sensed only to the nearest quadrant; 85 percent of these were sensed correctly. For the remaining 65 percent of the rounds, miss distances were estimated.

Figure 5 shows the cumulative percentage of rounds fired at each range as a function of the absolute difference between the estimated (BC scope) and measured miss distances. Rounds that struck the canvas panel are grouped separately in Fig. 5 from those that passed through the wire screen. It is evident from the graphs that rounds that passed through the panel were more precisely located than rounds that passed through the screen. This was due partly to the 1-ft scale clearly marked on the panel and partly to the well-defined holes left by a round passing through the panel. Positions of rounds passing through the screen had to be estimated by observing their tracers.

Appendix A

DATA-COLLECTION PLAN

Tables

Cant Experimental Procedure

(1) M60 tank is fired from a level position beside the ramp to establish or confirm zero daily.

(2) M60 tank equipped with standard reticle is driven to position on ramp, corresponding to 15 ± ½-deg cant.

(3) Gunner's quadrant is used to measure angle of cant.

(4) Applicable target, cant angle, and direction of cant are pointed out to gunner to avoid errors in gunner's judgment.

(5) Aim-off due to cant (engraved on modified reticle, estimated by gunner when using standard reticle) is sighted.

(6) Aim-off data are recorded before first round is fired.

(7) First round is fired, scored as target hit or miss, and recorded.

(8) If hit occurs, target at another range is directed to be engaged.

(9) If miss occurs, aim-off is adjusted from first-round sensing.

(10) Aim-off data are recorded before second round is fired.

(11) Second round is fired, scored, and recorded.

(12) Target at another range is directed to be engaged.

(13) Procedures 5 to 12 are repeated in order until firings have been conducted on targets at 800, 1200, and 1500 m.

(14) Second gunner repeats procedures 4 to 12.

(15) Targets and wire screens at 800, 1200, and 1500 m are measured for horizontal and vertical miss distances of rounds from origin of target and properly marked.

(16) Gunner's quadrant is used to measure angle of cant at end of specific cant-angle firing.

(17) Tank is driven to next position on ramp corresponding to next cant angle to be investigated (i.e., 15 deg L to 10 deg L to 5 deg L to 5 deg R to 10 deg R to 15 deg R).

(18) Procedures 2 to 17 are repeated for all 6 ramp positions. This completes TP-T firings using the standard reticle.

(19) Two of the four gunners are randomly selected to fire HEAT-T ammunition.

(20) Procedures 1 to 17 are followed with these modifications: (a) only the target at 2000 m is fired on, and (b) both gunners complete three positions on one side of the ramp before the target is scored and marked. This completes HEAT-T firings using the standard reticle.

(21) M60 tank is fitted with modified reticle for remaining firings.

(22) Procedures 1 to 20 are now repeated. This completes TP-T and HEAT-T firings with the modified reticle.

TABLE A1

Firing Order of Experiment

Cant angle, deg	Direction	Range, m, to target in order of engagement			
		Days 1–5 (25–29 June 1963), Standard Reticle, TP-T Ammunition		Days 7–9 (1–3 July 1963), Modified Reticle, TP-T Ammunition	
		Gunner A	Gunner B	Gunner E	Gunner F
15	L	800, 1500, 1200	1500, 1200, 800	800, 1500, 1200	1500, 1200, 800
10	L	1200, 800, 1500	1500, 1200, 800	1200, 800, 1500	1500, 1200, 800[b]
5	L	800, 1200, 1500	1200, 800, 1500	800, 1200, 1500	1200, 800, 1500
5	R	1200, 800, 1500	800, 1200, 1500	1200, 800, 1500	800, 1200, 1500
10	R	1500, 1200, 800	1200, 1500, 800	1500, 1200, 800	1200, 1500, 800
15	R	1500, 800, 1200	800, 1200, 1500	1500, 800, 1200	800, 1200, 1500
		Gunner C	Gunner D	Gunner G	Gunner H
15	L	1500, 1200, 800	800, 1200, 1500	1500, 1200, 800	800, 1200, 1500
10	L	800, 1200, 1500	800, 1500, 1200	800, 1200, 1500[c]	800, 1200, 1500
5	L	1500, 800, 1200	1500, 1200, 800	1500, 800, 1200	1500, 1200, 800
5	R	1200, 1500, 800	1500, 1200, 800	1200, 1500, 800	1500, 1200, 800
10	R	800, 1500, 1200	1200, 800, 1500	800, 1500, 1200	1200, 800, 1500
15	R	1500, 1200, 800	800, 1200, 1500	1500, 1200, 800	800, 1200, 1500
		Day 6 (30 June 1963), Standard Reticle, HEAT-T Ammunition		Days 9–10 (3–4 July 1963), Modified Reticle, HEAT-T Ammunition	
		Gunner A[a]	Gunner D[a]	Gunner E[d]	Gunner G[d]
15	L	2000	2000	2000	2000
10	L	2000	2000	2000	2000
5	L	2000	2000	2000	2000
5	R	2000	2000	2000	2000
10	R	2000	2000	2000	2000
15	R	2000	2000	2000	2000

[a]Two of the four gunners who fired TP-T ammunition with the standard reticle were randomly selected to fire HEAT-T ammunition with the standard reticle.

[b]On completion of 10-deg L cant firings, gunner F was injured and replaced by gunner G, who completed 5-deg L and 5-, 10-, and 15-deg R cant firings.

[c]On completion of 10-deg L cant firings, gunner G was replaced by gunner F, who completed 5-deg L and 5-, 10-, and 15-deg R cant firings.

[d]Two of the four gunners who fired TP-T ammunition with the modified reticle were randomly selected to fire HEAT-T ammunition with the modified reticle.

TABLE A2

Zeroing Information

Reticle	
Standard	Modified
Firing Ammunition	
TP-T, HEAT-T	TP-T, HEAT-T
Zeroing[a] Ammunition	
TP-T, HEAT-T	APDS-T APDS-T

[a]Zeroing range is 1200 m

Appendix B

MISS-DISTANCE DATA

Tables

TABLE B1

Miss Distances for TP-T Ammunition, Standard Reticle

(In feet)

Range, m	Direction	Gunner A, Round 1	Gunner A, Round 2	Gunner B, Round 1	Gunner B, Round 2	Gunner C, Round 1	Gunner C, Round 2	Gunner D, Round 1	Gunner D, Round 2
15 deg L									
800	Horizontal	−8	−6½	−8½	−4	−2½	—	−2½	—
	Vertical	−3	+5	−4	+13	−1	—	−1¼	—
1200	Horizontal	−9	−2	−14	−14½	+1½	—	0	+1½
	Vertical	−4½	−9½	−4¾	−5¾	+½	—	+4½	+½
1500	Horizontal	(−20)[a]	−1½	(−20)[a]	0	—	+¼	+1	+½
	Vertical	—	+3	—	+6	(−20)[a]	+2¾	+3½	+3¼
10 deg L									
800	Horizontal	−6	—	−6	—	−1	—	−2	—
	Vertical	−3¾	(+20)[a]	−3¾	(+20)[a]	−2½	—	−3	—
1200	Horizontal	−2	−15½	−14½	−3½	+2	—	−1	—
	Vertical	−9½	−8½	−7½	+6	+2¾	—	+2	—
1500	Horizontal	−16½	−6	−17½	+½	+5	−3	+4	—
	Vertical	−7	+10	−4	+10	+5	+1½	−3	—
5 deg L									
800	Horizontal	0	—	+½	—	−1½	—	+1	—
	Vertical	−¾	—	−¼	—	+2	—	−1	—
1200	Horizontal	0	—	−10	−1	+4	−1	(+20)[a]	+2
	Vertical	+2	—	+2	+1	+1½	+2½	—	+1
1500	Horizontal	−1	—	−1½	—	+2	−2	+10	+2½
	Vertical	+1	—	+3	—	+4	+1	−2	+4½
5 deg R									
800	Horizontal	+½	—	−¾	—	−1	—	−5	−1½
	Vertical	−½	—	0	—	+¾	—	+15	+1
1200	Horizontal	+9	+2	+4	+4	+6	+1	−½	—
	Vertical	0	+½	+¼	−½	+1¼	−2	+1¾	—
1500	Horizontal	+5	−3	+5	+5	−10	−½	+½	—
	Vertical	0	+4	+1	+½	+3½	+5	+3	—
10 deg R									
800	Horizontal	−¾	—	+½	—	−2	—	−½	—
	Vertical	−1½	—	−1	—	+1	—	+1	—
1200	Horizontal	—	+6	+6	−½	−4	+4	+1	—
	Vertical	(+20)[a]	−2	−1	+½	+1	+2	+1	—
1500	Horizontal	+6	−7	+7	−4½	−9	+4½	−6	0
	Vertical	+1½	−15	+½	0	+4	+3	+6½	+1½
15 deg R									
800	Horizontal	+8	+9½	+6	+1	+1	—	+½	—
	Vertical	0	0	−1	+5	+2	—	+1	—
1200	Horizontal	+9½	+4	+3	0	+3½	—	+4	—
	Vertical	0	−½	+8	−2	+2½	—	+2	—
1500	Horizontal	+17	(−4½)[a]	+15½	+16	−5	+1	+5½	0
	Vertical	−½	(+10)[a]	−2	−3	+7	+6	+2	+3½

[a]Observer-sensing data are enclosed in parentheses.

TABLE B2

Miss Distances for TP-T Ammunition, Modified Reticle

(In feet)

Range, m	Direction	Gunner A, Round 1	Gunner A, Round 2	Gunner B, Round 1	Gunner B, Round 2	Gunner C, Round 1	Gunner C, Round 2	Gunner D, Round 1	Gunner D, Round 2
15 deg L									
800	Horizontal	−1	0	0	—	−½	—	−1	—
	Vertical	+3½	−2	+2	—	+1	—	0	—
1200	Horizontal	−3	−2	−5	—	−5½	−2	−4½	−1
	Vertical	+4	+2½	+3	(−20)[a]	+2½	+½	+1	+2½
1500	Horizontal	−6	−7	−9	−7	−12	−5	−12	−8
	Vertical	−9	−10½	+3½	−3½	0	0	+1½	+½
10 deg L									
800	Horizontal	−½	—	0	—	−1½	—	−1	—
	Vertical	+1	—	+2¾	—	0	—	0	—
1200	Horizontal	(−15)[a]	−4½	−7	−2	−3	—	−6	−2½
	Vertical	(−6)[a]	+3½	+5	+2	−2	—	+2½	−½
1500	Horizontal	−4½	+1½	−17½	0	−6	−5	−10	−2
	Vertical	+4	+2¾	−2½	+2	−1	+½	+3½	+3
5 deg L									
800	Horizontal	−2	—	−3	—	−½	—	−1	—
	Vertical	+2	—	−½	—	+2	—	−1½	—
1200	Horizontal	−2	+2	−3	—	−3	0	−1½	—
	Vertical	+5	+1	+½	—	+4½	+3	−1½	—
1500	Horizontal	+¾	—	−2½	—	−12	+2	−3	—
	Vertical	+2	—	+3	—	−3½	+3½	+3	—
5 deg R									
800	Horizontal	−1	—	−7	−1	−1¼	—	−4	−3
	Vertical	−½	—	−1	+1½	+1½	—	+½	+½
1200	Horizontal	+10	+5	−3	+2	(+5)[a]	0	−2½	−1
	Vertical	+1	−1	+3½	+1	(+2½)[a]	0	+½	+2
1500	Horizontal	+3	—	−1	—	+8½	+5½	+½	—
	Vertical	+2¾	—	+3	—	+1½	0	+½	—
10 deg R									
800	Horizontal	−4	—	−4½	−4½	−4½	−2½	−½	—
	Vertical	0	—	0	0	0	−1	0	—
1200	Horizontal	+½	—	−5	+4	0	—	0	—
	Vertical	+1½	—	+4½	+1½	+½	—	+½	—
1500	Horizontal	+6	+1	+2	—	+6	+6½	+5	+1
	Vertical	+7½	+6½	+1	—	−1	0	0	−½
15 deg R									
800	Horizontal	−4	−2	−4½	−4	−5½	−5	−4	−3½
	Vertical	−½	−1	0	0	−½	0	0	−½
1200	Horizontal	+½	—	−2	—	+1	—	−½	—
	Vertical	+½	—	−1	—	+½	—	−1	—
1500	Horizontal	+8½	+7½	+9	0	+4½	+4	+6½	+6
	Vertical	0	−4	0	+3	−2½	−3	−1	0

[a]Observer-sensing data are enclosed in parentheses.

TABLE B3

Miss Distances for HEAT-T Ammunition[a]

(At 2000-m range; miss distance, in feet)

Gunner	Round number	15 deg L		10 deg L		5 deg L		5 deg R		10 deg R		15 deg R	
		Horiz	Vert	Horiz	Vert	Horiz	Vert	Horiz	Vert	Horiz	Vert	Horiz	Vert
Standard Reticle													
A	1	+8	+3	−7	−6	−6½	−1	+2	−1	+4	−4	0	+5
	2	−6	−5	+4½	+5	+2½	+2	—	—	+½	+3	−16	+½
D	1	−4½	+½	−6	−½	−3½	+5½	+½	+2	+5½	−4½	+2	+2
	2	−4½	+1	−12	−4½	−6	+2	—	—	+5	0	—	—
Modified Reticle													
E	1	+4	−2	0	−4	−6	0	−5	−2	−9	−½	−3	+1
	2	—	—	—	—	+2	+1½	+½	−4	−3½	0	—	—
G	1	+4	−4	+½	−1	−4	0	−6	−½	−7	+½	−5	0
	2	+2	−2½	+3	+3½	−3	−4	−2	−1	−1	1½	−3½	0

[a]For all firings with the modified reticle, except for Gunner E's round at 15-deg L cant, the canvas panel was rotated 90 deg, i.e., it was 8 ft high and 6 ft wide.

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